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ULTRASONIC STUDIES OF GELS

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(*Received for publication, August, 18, 1950*)

ABSTRACT. Using an ultrasonic pulse technique the elasticities of gels have been obtained at four ultrasonic frequencies. In this paper the effect of temperature and age on the iron silicate gels has been studied. A brief discussion outlines the probable structure and mechanism of gel formation, maintaining that the ultimate units in a gel are groups of atoms producing an interlinked fibrous structure perfectly randomly oriented.

In a series of papers the author has initiated a line of inquiry and study of the gelatinous state of matter quite new to the colloid chemists. The use of an ultrasonic pulse method (Srivastava, 1949) has been made to determine the elastic constants of four gels. In another paper the author (Srivastava, 1950) deals with the effect of temperature and frequency on the elasticities of a certain iron silicate gel. At that time no tentative theory was advanced regarding the mechanism or its structure. Thorium phosphate gel was studied by Prakash, Mehra and Srivastava (1950) in a similar manner.

The importance of this study is great since the information available so far is meagre and this field of inquiry had been almost completely ignored in the past. Furthermore, it is expected that the behaviour of elastic forces on gels will afford a better insight into these problems.

The method consists of a suitable ultrasonic pulse generator which supplies a beam of ultrasonic energy that impinges on a block of gel held vertically supported by a metallic frame immersed in a liquid bath. The slab is capable of rotation in a vertical plane thereby changing the angle of incidence of the beam. Since the velocity in the gel is greater than that in the liquid, the wave-trains are refracted away from the normal. Consequently the rotation of the block results in a vanishing of the emergent rays due to total reflection. The waves in the gel take up two velocities depending upon the two associated deformations of shear and longitudinal extension. The amplitude of the transmitted waves therefore shows two minimum and if V_s and V_l are the two velocities then we have

$$V_s = \sqrt{\frac{S}{\rho}}$$

$$V_l = \sqrt{\frac{(1-\sigma)E}{(1+\sigma)(1-2\sigma)\rho}} .$$

where ρ is the density of the gel, E and S are the modulii of elongation an shear. If V_x is the velocity in the tank liquid, which is usually water, then

$$V_l = V_x/\sin\theta_1$$
$$V_s = V_x/\sin\theta_2.$$

from which V_l and V_s can be known. Then from the well known relations

$$E = 2\,(1+\sigma)S$$

and,
$$\sigma = \frac{(V_l/V_s)^2 - 2}{2[(V_l/V_s)^2 - 1]}$$

all the elastic constants can be calculated.

In the accompanying figures the variation of Young's modulus with temperature, age and frequency have been shown. A set of values for the velccity have been also shown in Fig. 2. The two dips in the transmitted wave amplitude are seen in Fig. 4. A detailed account of these can be seen in the author's other papers (Srivastava, 1950).

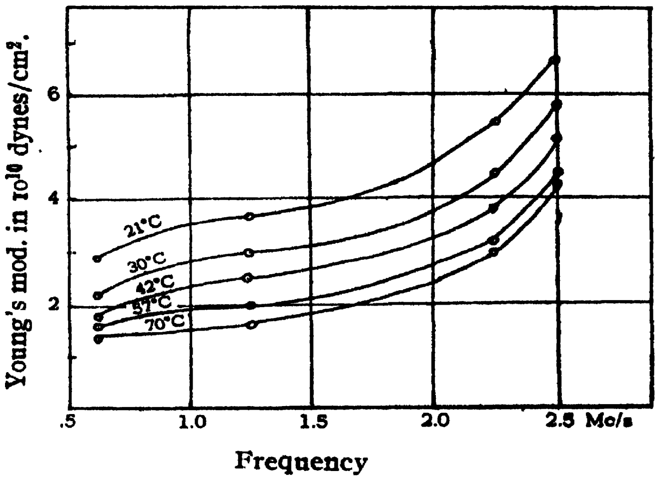


FIG. 1
Variation of Young's modulus with freqnency and temperature

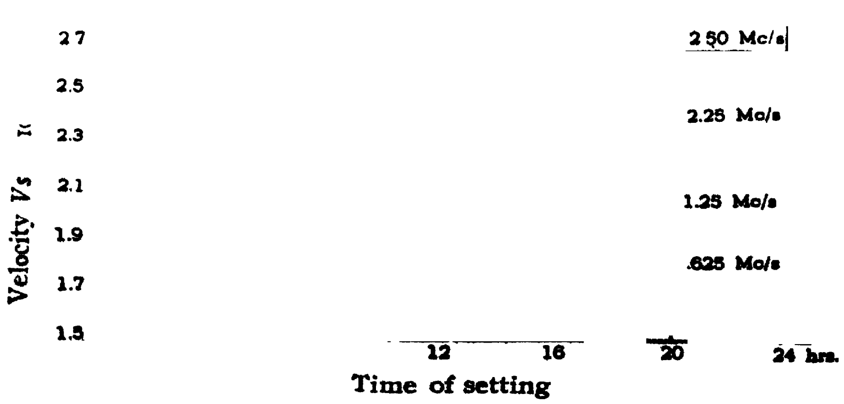
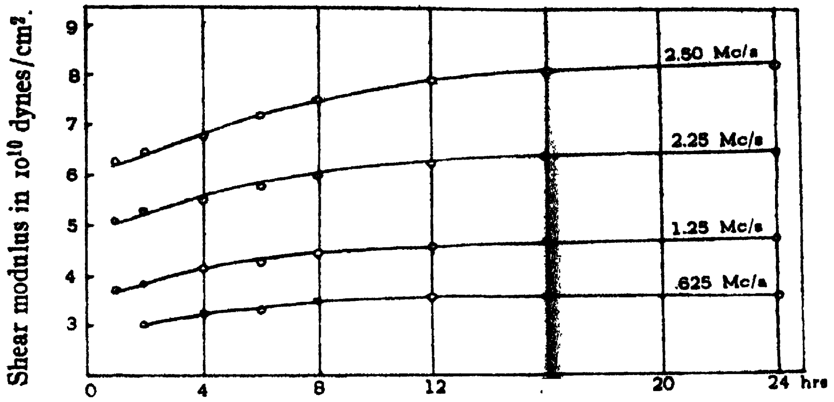


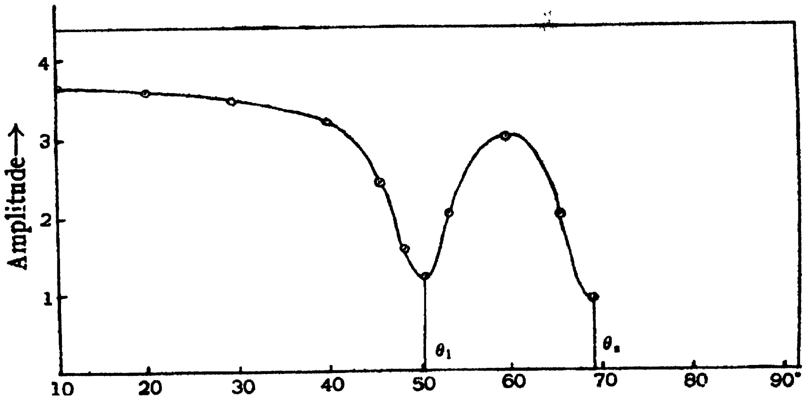
FIG. 2
The shear wave velocity attaining a constant value after twelve hours for the 4 frequencies at 30°C



Time of setting

FIG 3

Variation of shear modulus with the time of setting for four frequencies at 30°C



Angle of incidence→

FIG. 4

Variation of amplitude of transmitted waves on altering the angle of incidence for one observation of θ_0 and θ_s

Though still far from advancing a theory on the exact nature of the mechanism of gel formation and its structure the author, however, has drawn the following conclusions from the data published here and elsewhere (Srivastava, 1950):

The resistance to elastic forces implies that the units in a gel are themselves capable of a similar behaviour. These units, therefore, themselves cannot be atoms; for then larger forces would be required to cause these elongations and shears. The forces required to increase the distance between the adjacent atoms would be comparatively far in excess over that for which the author has accounted in his investigations. It follows, therefore, that the structure should be of the form of groups of atoms to account for the observed elasticities. The elastic processes therefore suggest the following factors.

(*a*) Groups of atoms producing strong and flexible units:

(*b*) The forces of cohesion around these fibres must be weak and uniform to account for the changes in state at higher temperatures.

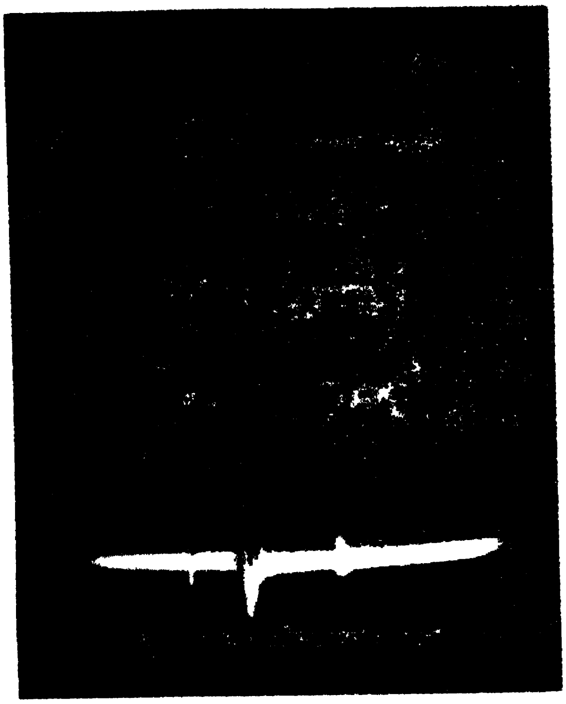


FIG. 5
The oscillogram
The central vertical displacement being the transmitted wave

(*c*) An interweaving of the fibres in the three dimensional lattices to account for the looseness of the entire structure.

(*d*) And a perfectly random orientation of the fibres to account for the lack of any anisotropy in the gels studied.

It is clear that the water enmeshed in overwhelmingly large proportions in a gel is chiefly due to the interlacing of the fibres in a three dimensional framework which leaves enough free space for water. Further work is in progress in this laboratory to elucidate these processes more generally.

ACKNOWLEDGMENTS

In conclusion the author takes this opportunity to thank Dr. R. N, Ghosh for his help in the development of the technique and to Mr. Ravindra Kumar for his help in calculating the results.

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